Internet Appendix for "Algorithmic Underwriting in High Risk Mortgage Markets"

This appendix supplements the empirical analysis of this paper. Below is a list of the sections contained in this appendix.

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A Sample Construction and Choices

A The Ginnie Mae-HMDA match

We merge the Ginnie Mae and HMDA data using FHA endorsements as an intermediate link. The FHA endorsements data contains the universe of single-family mortgages insured by the FHA and is published on the U.S. Department of Housing and Urban Development (HUD)'s website.[1]

To merge the Ginnie Mae data and FHA endorsements, we take a two-step approach. In the first step, we exact match on the property state, interest rate, the balance of the mortgage rounded down to the nearest 1000, whether the mortgage is fixed rate, the mortgage purpose, and whether the mortgage's endorsement month is within 3 months of origination. In the second step, we take the unique matches from the first step and identify a seller-lender correspondence by keeping only the Ginnie Mae sellers that are among the top 10 sellers associated with the matched endorsement FHA lender (sponsor) and that have a market share of at least 5% associated with the matched endorsement FHA lender (sponsor). As the average seller market share is 57% for the top seller associated with each sponsor, this is a fairly permissive restriction. Overall, we were able to uniquely merge 62% of Ginnie Mae loans to FHA endorsements.

To merge the HMDA data and FHA endorsements, we also take a two-step approach. In the first step, we match on whether the property's zip code in the endorsement data contains a Census tract with a positive residential ratio that is associated with the HMDA data as found in HUD's March 2016 crosswalk,[2] the balance of the mortgage rounded to the nearest 1000, the mortgage purpose, and whether the mortgage's endorsement month is either in the HMDA's year of origination or within 3 months of it. In the second step, we take the unique matches from the first step and identify a lender-FHA sponsor correspondence by keeping only the HMDA lenders that have a market share of at least 20% associated with the matched endorsement FHA sponsor. As in theory the correspondence between HMDA lenders and FHA sponsors should be one-to-one and the average market share for the top lender associated with each sponsor in our first step matched sample is 91%, this is a fairly permissive restriction. Overall, we were able to uniquely merge 81% of FHA endorsements to HMDA loans.

Linking the datasets together, we obtain a total unique match rate of 49%. Restricting to new purchase, single-family, non-manufactured housing mortgages in our sample period, the match rate is 43%. We use only the uniquely matched loans for our empirical analyses. To alleviate concerns about match quality, we also run our extensive margin and loan performance analysis on the Ginnie Mae sample alone, and obtain similar qualitative results. These results are tabulated in Table A.1.

[1] https://www.hud.gov/program_offices/housing/rmra/oe/rpts/sfsnap/sfsnap.

[2] https://www.huduser.gov/portal/datasets/usps_crosswalk.html

Table A.1. Results from the Ginnie Mae Sample

This table examines the changes in loan origination volume and loan performance around the changes in FHA underwriting regulations. The sample is our Ginnie Mae sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017, excluding August 2016, the month of the policy implementation. DTI is winsorized at the 1st and 99th percentiles and rounded up to the nearest integer. Panel A replicates Table 2, based on the methodology described in Section 4.2. Panel B examines the changes in mortgage delinquency rates around the FHA policy change following Equation 7. The analysis follows the one in Table 3, with the exception that we do not control for borrower income and county and lender fixed effects because those variables come from HMDA data. Instead, we include state fixed effects in Columns (3) and (6). Standard errors in Panel A are reported in parentheses and are computed from 1,000 bootstrap replications clustered by origination month. Standard errors in Panel B are double clustered by DTI (integer level) and origination month. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Panel A. Effects on Credit Quantity

	Baseline	Alternative Specifications		
Threshold:	$\overline{d} = 35$	$\overline{d} = 32$	$\overline{d} = 34$	$\overline{d} = 36$
Δ*Loans Originated*	0.065***	0.061***	0.064***	0.066***
	(0.011)	(0.013)	(0.011)	(0.011)
g(Volume) (High DTI)	1.031***	0.993***	1.015***	1.037***
	(0.049)	(0.051)	(0.048)	(0.052)
g(Volume) (Low DTI)	-0.117***	-0.099***	-0.109***	-0.124***
	(0.020)	(0.019)	(0.018)	(0.020)
Δ*Low DTI Loans*	-0.065***	-0.066***	-0.065***	-0.064***
	(0.011)	(0.012)	(0.011)	(0.011)
Δ*Average DTI*	1.180***	1.171***	1.174***	1.178***
	(0.073)	(0.071)	(0.072)	(0.075)
Number of Observations	1,692,934	1,692,934	1,692,934	1,692,934

Panel B. Effects on Delinquency

Sample	High DTI ($43 < DTI \leq 50$)			Low DTI ($35 \leq DTI \leq 43$)		
Dep. Var.: *Delinquency*	(1)	(2)	(3)	(4)	(5)	(6)
Treated × Post	-0.00250	-0.00334	-0.00120	0.00335	0.00455	0.00543
	(0.0108)	(0.0110)	(0.0106)	(0.00386)	(0.00391)	(0.00384)
Controls		Yes	Yes		Yes	Yes
Month FE	Yes			Yes		
FICO FE	Yes			Yes		
FICO-DTI FE		Yes	Yes		Yes	Yes
Month-DTI FE		Yes	Yes		Yes	Yes
State FE			Yes			Yes
Observations	465363	465352	465351	487894	487885	487885
R^2	0.028	0.029	0.040	0.028	0.029	0.038

B Algorithmic underwriting in the DTI>50 region

In this subsection we examine the risk management effectiveness of algorithms in the DTI>50 region for low-FICO borrowers. We note that human underwriting is not allowed for DTI>50, low-FICO borrowers throughout our sample period. On the other hand, algorithms are allowed to underwrite DTI>50, low-FICO

borrowers post-policy. Therefore, the borrowers in this DTI region allows us to analyze the risk management effectiveness of the FHA's underwriting algorithm when they alone can approve borrowers.

We begin by adapting the DeFusco et al. (2020) methodology to quantify the credit expansion in this region, and then examine delinquency rates. In theory, there should be no loans in low FICO, DTI>50 region pre-policy, as humans were unable to underwrite in this region. In practice, there are 95 such loans observed in our dataset, likely due to administrative errors. To adapt the DeFusco et al. (2020) methodology for the DTI>50 region, we set the counterfactual loan volume in the DTI>50 region equal to their pre-policy quantities:

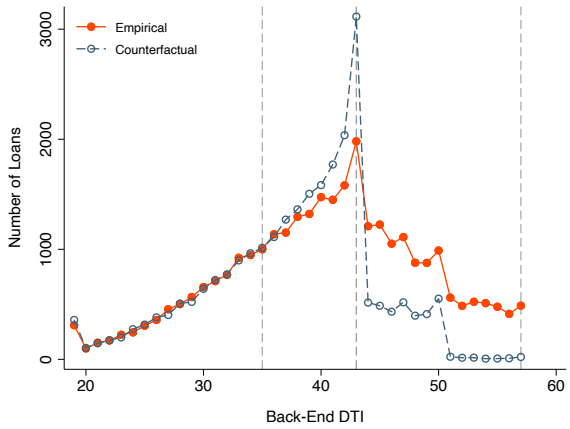
$$\hat{n}_{ld}^{post} = n_{ld}^{pre}, \text{ for } d > 50. \tag{12}$$

Figure A.1 shows the bunching estimates using the adapted DeFusco et al. (2020) methodology. Inspecting Figure A.1, we find that algorithms approved approximately as many loans in the DTI>50 region post-policy relative to the no-policy counterfactual in the 43–50 DTI region pre-policy, which suggests that algorithms were able to significantly expand credit supply in the DTI>50 region.

We then examine the delinquency risk of this purely algorithmically underwritten population, by comparing to DTI 43–50 low-FICO borrowers post-policy. Table A.2 shows that the low-FCIO borrowers in the DTI>50 region have even lower default risk than DTI 43–50 low-FICO borrowers post-policy, with 10% statistical significance in our fully saturated specification in column (3), suggesting that algorithms are able to significantly expand credit supply while controlling risk within the DTI>50 region, as consistent with our main results.

One explanation for the lower delinquency rates in the DTI>50 region post-policy, as compared to the DTI 43–50 region post-policy, is that algorithms may have been more restrictive with their credit supply in this region. This can be seen in the kink downwards in terms of a drop-off in the number of loans originated right after the DTI=50 cut-off in Figure A.1. Interestingly, Figure A.1 also shows that there is limited bunching at DTI=50 either pre-policy or post-policy, which suggests that unlike the DTI=43 point there may have been less intensive margin adjustment of DTI around DTI=50.

Figure A.1. Bunching analysis, including DTI>50 region with no human underwriting



Note: This figure plots the empirical and counterfactual distributions of FHA single-family, non-manufactured housing new purchase mortgages in our Ginnie Mae-Endorsements-HMDA sample 12 months after the policy, while including the $DTI > 50$ region. DTI is winsorized at the 1st and 99th percentiles and rounded up to the nearest integer. Dashed lines are drawn at DTI equals 43, above which the policy takes effect.

Table A.2. Delinquency Rates: DTI over 50

This table examines the changes in mortgage delinquency rates around the changes in underwriting regulations. The sample is our Ginnie Mae-HMDA sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017, excluding August 2016, the month of the policy implementation. The sample consists of borrowers with credit scores below 620, DTI>43, and loan origination date after the regulation change in August 2016. *DTI>50* represents an indicator for borrowers with DTI greater than 50. Controls include log of loan amount and log of borrower household income. Standard errors are reported in parentheses and are double clustered by DTI (integer level) and origination month. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Delinquency Rates, within Post-Treatment Sample

Sample	High DTI (> 43)		
Dep. Var.: *Delinquency*	(1)	(2)	(3)
DTI>50	-0.00168	-0.00609	-0.0124*
	(0.00653)	(0.00647)	(0.00659)
Controls		Yes	Yes
Month FE	Yes	Yes	Yes
FICO FE	Yes	Yes	Yes
County FE			Yes
Lender FE			Yes
Observations	10779	10771	10075
R^2	0.002	0.006	0.149

C The Experian-Ginnie Mae match

We enrich the individual-year observations in the Experian data that had a new FHA mortgage origination with Ginnie Mae data, which contains more information about the details of the new FHA mortgage origination. We continue to use the FHA endorsements as an intermediate link, and use the Ginnie Mae-FHA endorsements data described in Section A as the starting point of the merge.

To conduct the merge, we use the following variables common to both datasets: the zip code of the property, the origination month, the original mortgage amount, and whether the borrower has co-applicants. In the Ginnie Mae-FHA endorsement data, these variables identify loans with 99.13% uniqueness. We drop the non-unique loans based on these variables in the Ginnie Mae-FHA endorsement data, and merge them with the Experian data.

The match rate, which we define as the fraction of loans within the Experian data that are merged to unique loans in the Ginnie Mae-FHA endorsement data, is given by year in Table A.3. A match rate below 62% is expected, due to the fact that the Ginnie Mae-endorsement data is only 62% of the original Ginnie Mae data as described in Section A. The match rates range between 41% to 53%, depending on year, which are not far from the maximum value of 62% on average. In the baseline analyses for Section 8.2, we weigh the individual-year observations with new FHA mortgages by the inverse of these year-specific match rates, effectively assuming that the matched sample is representative, in regression analyses that utilize merged variables. We also show results without matching and weighting in Table F.1.

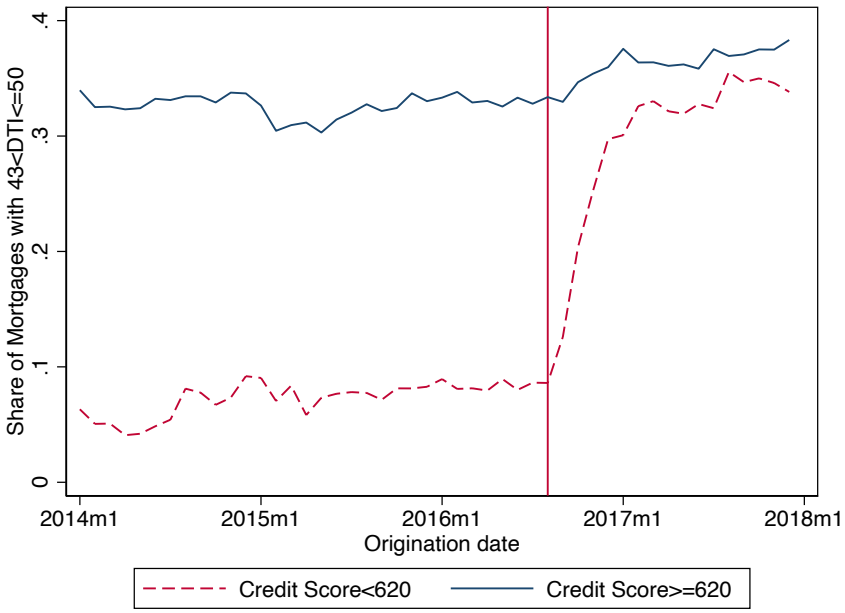
Table A.3. Match rate by year

Year	2014	2015	2016	2017	2018	2019
Match Rate	0.443	0.454	0.414	0.497	0.530	0.503

B Additional Results on Credit Quantity Effects

A Effect of the policy change in full sample

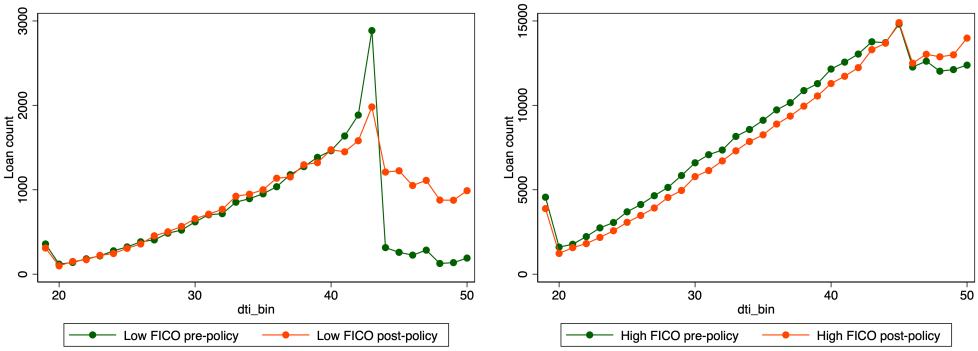
Figure B.1. Effect of the policy change, Ginnie Mae-HMDA sample



Note: This figure plots the share of FHA new purchase, single-family, non-manufactured housing mortgages with an DTI greater than 43 and less than or equal to 50 by their month of origination. The sample is the Ginnie Mae-HMDA sample from January 2015 to December 2017 with DTI less than or equal to 50. Data for borrowers with a credit score less than 620 and a credit score greater than or equal to 620 are separately plotted. The policy month of August 2016 is marked via a vertical red line.

B Raw data for Bunching Analysis

Figure B.2. Raw Data Input

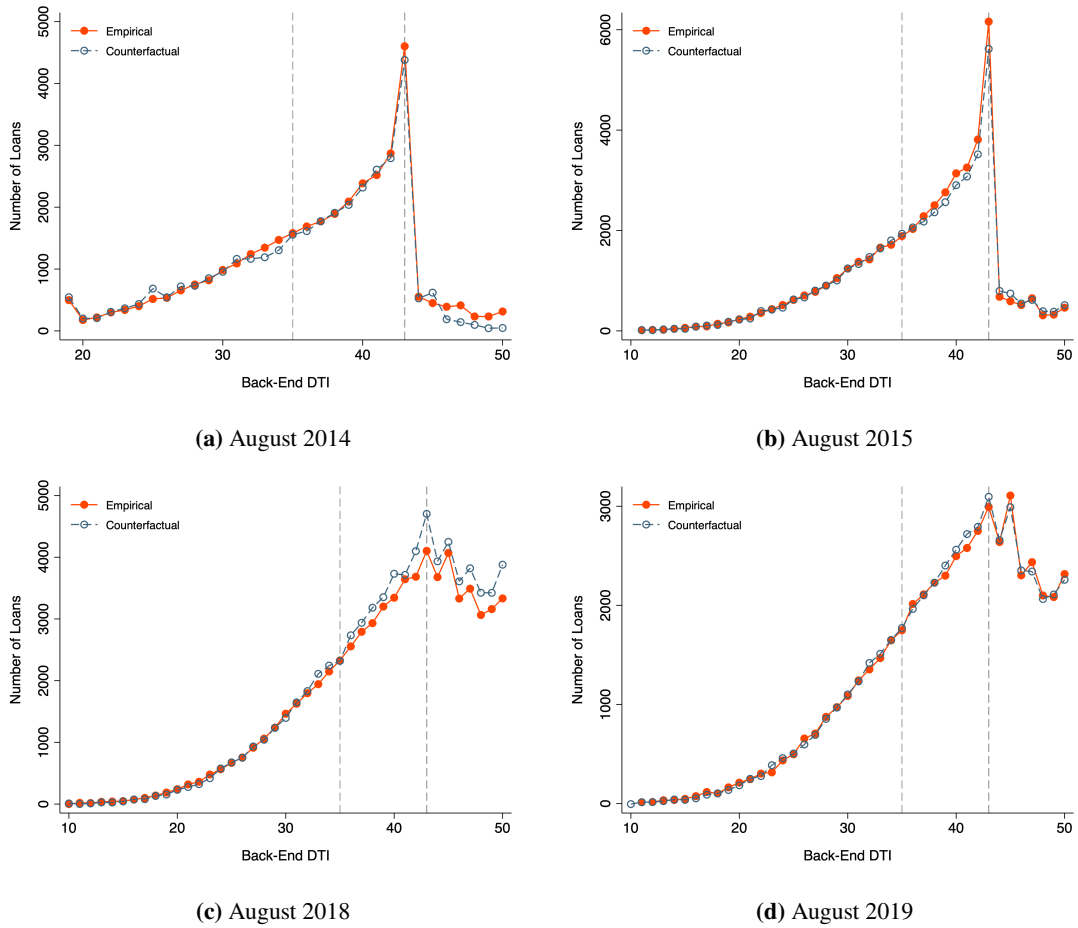


(a) Low FICO **(b)** High FICO

Note: This figure plots empirical numbers of FHA single-family new purchase mortgages in our Ginnie Mae-Endorsements-HMDA sample pre- and-post policy, separately for low (below 620) and high (above 620) FICO borrowers. DTI is winsorized at the 1st and 99th percentiles and rounded up to the nearest integer.

C Placebo Bunching Analysis

Figure B.3. Placebo Bunching Analysis



(a) August 2014

(b) August 2015

(c) August 2018

(d) August 2019

Note: This figure plots empirical and counterfactual numbers of FHA single-family new purchase mortgages in our Ginnie Mae sample around various pseudo policy dates, based on the methodology described in Section 4.2. DTI is winsorized at the 1st and 99th percentiles and rounded up to the nearest integer. Dashed lines are drawn at DTI equals 43, above which the policy takes into affect, and at DTI equals 35, at or below which we assume is unaffected by the policy for our baseline bunching analysis. The sample consists of loans 12 months prior to and 12 months following the specified month, excluding the specified month.

C Additional Evidence for Delinquency Analysis

Table C.1. Delinquency Rates: Longer Time Horizon

This table examines the changes in mortgage delinquency rates around the changes in underwriting regulations. The sample is our Ginnie Mae-HMDA sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017, excluding August 2016, the month of the policy implementation. DTI is winsorized at the 1st and 99th percentiles and rounded up to the nearest integer. We report results for 3-year, 4-year, and 5-year delinquencies. *Treated* is an indicator that equals one if the borrower's credit score is below 620, and zero otherwise. *Post* indicates whether the loan is extended after the regulation change in August 2016. *High DTI* (*Low DTI*) represents a subsample of borrowers with DTI above 43 (less than or equal to 43). Borrowers with DTI below 35 are unaffected by the policy and are excluded from the sample. Controls include log of loan amount and log of borrower household income. Standard errors are reported in parentheses and are double clustered by DTI (integer level) and origination month. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Panel A. 3 Year Delinquency, Difference-in-difference Results

Sample	High DTI ($43 < DTI \leq 50$)			Low DTI (≤ 43)		
Dep. Var.: *Delinquency (3 year)*	(1)	(2)	(3)	(4)	(5)	(6)
Treated × *Post*	-0.0112	-0.0131	-0.00620	0.00581	0.00601	0.00808
	(0.0140)	(0.0131)	(0.0143)	(0.00684)	(0.00708)	(0.00755)
Controls		Yes	Yes		Yes	Yes
Month FE	Yes			Yes		
FICO FE	Yes			Yes		
FICO-DTI FE		Yes	Yes		Yes	Yes
Month-DTI FE		Yes	Yes		Yes	Yes
County FE			Yes			Yes
Lender FE			Yes			Yes
Observations	193092	192570	192226	203345	202698	202375
R^2	0.049	0.052	0.086	0.043	0.047	0.079

Panel B. 4 Year Delinquency, Difference-in-difference Results

Sample	High DTI ($43 < DTI \leq 50$)			Low DTI (≤ 43)		
Dep. Var.: *Delinquency (4 year)*	(1)	(2)	(3)	(4)	(5)	(6)
Treated × *Post*	-0.00623	-0.00769	0.000996	0.00428	0.00403	0.00679
	(0.0136)	(0.0134)	(0.0159)	(0.00663)	(0.00659)	(0.00749)
Controls		Yes	Yes		Yes	Yes
Month FE	Yes			Yes		
FICO FE	Yes			Yes		
FICO-DTI FE		Yes	Yes		Yes	Yes
Month-DTI FE		Yes	Yes		Yes	Yes
County FE			Yes			Yes
Lender FE			Yes			Yes
Observations	193092	192570	192226	203345	202698	202375
R^2	0.053	0.057	0.092	0.052	0.056	0.090

Panel C. 5 Year Delinquency, Difference-in-difference Results

Sample	High DTI ($43 < DTI \leq 50$)			Low DTI (≤ 43)		
Dep. Var.: *Delinquency (5 year)*	(1)	(2)	(3)	(4)	(5)	(6)
Treated × *Post*	-0.00816	-0.00986	-0.000102	-0.00375	-0.00414	-0.00163
	(0.0137)	(0.0131)	(0.0157)	(0.00799)	(0.00786)	(0.00870)
Controls		Yes	Yes		Yes	Yes
Month FE	Yes			Yes		
FICO FE	Yes			Yes		
FICO-DTI FE		Yes	Yes		Yes	Yes
Month-DTI FE		Yes	Yes		Yes	Yes
County FE			Yes			Yes
Lender FE			Yes			Yes
Observations	193092	192570	192226	203345	202698	202375
R^2	0.045	0.049	0.088	0.047	0.052	0.089

Table C.2. Delinquency Rates: 30 and 60 Day Measures

This table examines the changes in mortgage delinquency rates around the changes in underwriting regulations. The sample is our Ginnie Mae-HMDA sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017, excluding August 2016, the month of the policy implementation. DTI is winsorized at the 1st and 99th percentiles and rounded up to the nearest integer. Panel A reports results from the DID analysis following Equation 7 for 2 year, 30-day delinquencies, and Panel B reports 2 year, 60-day delinquencies. *Treated* is an indicator that equals one if the borrower's credit score is below 620, and zero otherwise. *Post* indicates whether the loan is extended after the regulation change in August 2016. *High DTI* (*Low DTI*) represents a subsample of borrowers with DTI above 43 (less than or equal to 43). Borrowers with DTI below 35 are unaffected by the policy and are excluded from the sample. Controls include log of loan amount and log of borrower household income. Standard errors are reported in parentheses and are double clustered by DTI (integer level) and origination month. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Panel A. 30-Day Delinquency, Difference-in-difference Results

Sample	High DTI ($43 < DTI \leq 50$)			Low DTI (≤ 43)		
Dep. Var.: *Delinquency (30 day)*	(1)	(2)	(3)	(4)	(5)	(6)
Treated × *Post*	-0.000310	0.00249	0.00798	0.00403	0.00380	0.00898
	(0.0159)	(0.0167)	(0.0166)	(0.00621)	(0.00621)	(0.00675)
Controls		Yes	Yes		Yes	Yes
Month FE	Yes			Yes		
FICO FE	Yes			Yes		
FICO-DTI FE		Yes	Yes		Yes	Yes
Month-DTI FE		Yes	Yes		Yes	Yes
County FE			Yes			Yes
Lender FE			Yes			Yes
Observations	193092	192570	192226	203345	202698	202375
R^2	0.065	0.069	0.105	0.071	0.076	0.111

Panel B. 60-Day Delinquency, Difference-in-difference Results

Sample	High DTI ($43 < DTI \leq 50$)			Low DTI (≤ 43)		
Dep. Var.: *Delinquency (60 day)*	(1)	(2)	(3)	(4)	(5)	(6)
Treated × *Post*	-0.0146	-0.0147	-0.0101	0.00867	0.00858	0.0109
	(0.0112)	(0.0105)	(0.0106)	(0.00499)	(0.00483)	(0.00583)
Controls		Yes	Yes		Yes	Yes
Month FE	Yes			Yes		
FICO FE	Yes			Yes		
FICO-DTI FE		Yes	Yes		Yes	Yes
Month-DTI FE		Yes	Yes		Yes	Yes
County FE			Yes			Yes
Lender FE			Yes			Yes
Observations	193092	192570	192226	203345	202698	202375
R^2	0.042	0.045	0.082	0.043	0.047	0.082

Table C.3. Delinquency Rates: Excluding CRA tracts

This table examines the changes in mortgage delinquency rates around the changes in underwriting regulations. The sample is our Ginnie Mae-HMDA sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017, excluding August 2016, the month of the policy implementation. Low-income census tracts that qualify for the Community Reinvestment Act (CRA) assessment in the year of mortgage origination are excluded from this analysis. CRA data is obtained from Chen et al. (2025). DTI is winsorized at the 1st and 99th percentiles and rounded up to the nearest integer. *Treated* is an indicator that equals one if the borrower's credit score is below 620, and zero otherwise. *Post* indicates whether the loan is extended after the regulation change in August 2016. *High DTI* (*Low DTI*) represents a subsample of borrowers with DTI above 43 (less than or equal to 43). Borrowers with DTI below 35 are unaffected by the policy and are excluded from the sample. Controls include log of loan amount and log of borrower household income. Standard errors are reported in parentheses and are double clustered by DTI (integer level) and origination month. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Sample	High DTI ($43 < DTI \leq 50$)			Low DTI (≤ 43)		
Dep. Var.: *Delinquency (90 day)*	(1)	(2)	(3)	(4)	(5)	(6)
Treated × *Post*	-0.01000	-0.0106	-0.00872	-0.00514	-0.00511	-0.00355
	(0.0103)	(0.0107)	(0.0106)	(0.00786)	(0.00816)	(0.00811)
Controls		Yes	Yes		Yes	Yes
Month FE	Yes			Yes		
FICO FE	Yes			Yes		
FICO-DTI FE		Yes	Yes			Yes
Month-DTI FE		Yes	Yes			Yes
County FE			Yes			Yes
Lender FE			Yes			Yes
Observations	156408	155958	155565	165756	165210	164858
R^2	0.030	0.033	0.072	0.029	0.033	0.070

D Additional Heterogeneity Analyses

A Propensity-Score Weighting of Race Subsamples by Income

This section provides more details regarding the covariance-balanced propensity score (CBPS) weighting approach used in Panel C of Table 5. The algorithm allows us to balance non-Black borrower's adjusted income, i.e. application income relative to the area median (AMI), to match those of Black borrowers. Specifically, we follow the methodology of Imai and Ratkovic (2014) to generate weights based on following covariates X_i for each borrower i, separately pre-and-post policy:

$$\begin{aligned} X_i = \{&\text{adjusted\_income}_i, \text{adjusted\_income\_sq}_i, \text{Low FICO}_i, \\ &\text{adjusted\_income}_i \times \text{Low FICO}_i, \text{adjusted\_income\_sq}_i \times \text{Low FICO}_i\}, \end{aligned}$$

where $adjusted\_income_i$ and $adjusted\_income\_sq_i$ are continuous variables representing the adjusted income of the borrower and its squared term. $Low\ FICO_i$ is an indicator for whether the borrower has FICO<620. From our regression sample, 0.22% of Black borrowers and 0.30% of white borrowers are not assigned a weight and are excluded from the sample. Table D.1 shows that the distributions of the adjusted income of Black and non-Black borrowers are well-balanced after weighting, both across low- and high-FICO groups and pre- and post-policy.

Table D.1. Post-Weighting Summary Statistics on $adjusted\_income_i$ by FICO Group and Race

Panel A: Pre-policy

	Race	Mean	SD	P10	P25	Median	P75	P90
Low FICO	Black	1.084	0.604	0.567	0.726	0.981	1.321	1.700
	Non-Black	1.084	0.604	0.561	0.730	0.987	1.311	1.685
High FICO	Black	0.953	0.478	0.470	0.617	0.846	1.173	1.563
	Non-Black	0.953	0.478	0.468	0.611	0.851	1.186	1.562

Panel B: Post-policy

	Race	Mean	SD	P10	P25	Median	P75	P90
Low FICO	Black	1.092	0.486	0.583	0.747	0.998	1.333	1.709
	Non-Black	1.092	0.486	0.579	0.751	1.009	1.326	1.701
High FICO	Black	0.971	0.486	0.484	0.632	0.866	1.193	1.592
	Non-Black	0.971	0.486	0.482	0.630	0.873	1.205	1.577

B Nonparametric Weighting of Race Subsamples by Income

We provide results on an alternative matching approach. Instead of re-weighting each individual loan by their propensity scores, we compute weights from a non-parametric method by FICO-income grids. Specifically, we group adjusted household income into buckets of 0.1, and for each FICO score-income bucket, we compute weights w as the relative likelihood that the bucket contains non-Black borrowers relative to black borrowers ($w = \frac{\#NonBlack}{Black}$). This weight is assigned to non-Black borrowers in that FICO-income grid, and can be viewed as a population weights that "correct" the density distribution of non-Black borrowers in that grid, so their overall income distribution becomes identical to that of Black borrowers. Loans to Black borrowers are assigned a weight of 1.

Table D.2. Heterogeneity by Race, Non-parametric Weighting by Income

This table examines the heterogeneity effects of the FHA underwriting policy across racial and income groups. The key variables are defined in the same way as in Table 5. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Panel D: Race Partition After Non-Parametric Weighting by Income

Subsample:	Black	Non-Black	Difference (Black - Non-Black)
Outcome: *Volume Change*			
Δ*Loans Originated*	-0.010	0.071***	-0.081**
	(0.038)	(0.012)	(0.038)
g(Volume) (High DTI)	0.859***	1.218***	-0.359**
	(0.151)	(0.071)	(0.162)
Outcome: *Delinquency Change (Coeff on Treated* $\times$ *Post)*			
High DTI:	0.026	-0.014	0.041
	(0.029)	(0.012)	(0.027)
Low DTI:	-0.000	0.002	-0.002
	(0.012)	(0.006)	(0.013)

C Additional heterogeneity analysis by race and ethnicity

Table D.3. Change in FICO by Race and Income

This table examines the changes in observed FICO scores around the changes in underwriting regulations. The sample is our Ginnie Mae-HMDA sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017, excluding August 2016, the month of the policy implementation. The sample consists of borrowers with DTI between 43 and 50. Controls consist of the dummy variable indicating whether the loan is originated by the treated group of borrowers with FICO<620. Standard errors are reported in parentheses and are double clustered by DTI (integer level) and origination month. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Panel A: Race

Sample:	High DTI ($43 < DTI \leq 50$)		
Dep. Var.: *FICO*	(1)	(2)	(3)
Subsample:	Black	Non-Black	Difference (Black - Non-Black)
Treated × *Post*	1.941	5.686***	-3.744*
	(1.829)	(1.220)	(1.814)
Controls	Yes	Yes	–
County FE	Yes	Yes	–
Lender FE	Yes	Yes	–
Month FE	Yes	Yes	–
Observations	24,615	168,212	–
R^2	0.285	0.195	–

Panel B: Income

Sample:	High DTI ($43 < DTI \leq 50$)		
Dep. Var.: *FICO*	(1)	(2)	(3)
Subsample:	Low Income	High Income	Difference (Low - High Income)
Treated × *Post*	5.772***	4.619***	1.259
	(1.596)	(1.125)	(1.227)
Controls	Yes	Yes	–
County FE	Yes	Yes	–
Lender FE	Yes	Yes	–
Month FE	Yes	Yes	–
Observations	109,774	82,908	–
R^2	0.182	0.252	–

Table D.4. Heterogeneity by Ethnicity

This table examines the changes in loan origination volume and delinquency rates around the changes in underwriting regulations for Hispanic and non-Hispanic borrowers. Δ*Loans Originated* refers to the increase in the total number of new purchase loans extended to low FICO borrowers as a fraction of the number of new purchase loans extended to low FICO borrowers in the absence of the policy. *g(Volume) (High DTI)* refers to the increase in the total number of new purchase loans extended to borrowers with FICO below 620 and DTI within 43–50 after the policy change as a fraction of the counterfactual number of new purchase loans for those borrowers in the absence of the policy. The methodology is described in Section 4.2. *Difference* represents the difference in coefficient estimates between each subsample partition and the statistical significance of the gap. The methodology is described in Section 4.2. The sample is our Ginnie Mae-HMDA sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017, excluding August 2016, the month of the policy implementation. DTI is winsorized at the 1st and 99th percentiles and rounded up to the nearest integer. Standard errors are reported in parentheses and are from 1,000 bootstrap replications clustered by origination month for the bunching analyses, and two-way clustered by origination month and DTI for regression analyses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

	Hispanic	Non-Hispanic	Difference (Hispanic - Non-Hispanic)
Volume Change			
Δ*Loans Originated*	0.077*	0.063***	0.014
	(0.041)	(0.013)	(0.042)
$g(Volume)(HighDTI)$	1.224***	1.207***	0.017
	(0.202)	(0.080)	(0.218)
Delinquency Change (Coeff on Treated X Post)			
High DTI:	-0.046	-0.000	-0.045*
	(0.026)	(0.012)	(0.023)
Low DTI:	-0.012	0.003	-0.016
	(0.015)	(0.007)	(0.016)

D Propensity score weighting of lender type and bank size by indirect seller status

In Panel B of Table 7, we use the covariance-balanced propensity score (CBPS) weighting approach to balance indirect sellers' lender type (i.e., bank vs non-bank) and bank size (i.e., asset size) to match those of direct sellers. We use the methodology of Imai and Ratkovic (2014) to generates weights based on following covariates X_i for each borrower i, separately pre-and-post policy:

$$X_i = \{\text{bank}_i, \text{bank}_i \times \text{log\_assets}_i, \text{bank}_i \times \text{log\_assets\_sq}_i, \text{Low FICO}_i$$
$$\text{bank}_i \times \text{Low FICO}_i, \text{bank}_i \times \text{log\_assets}_i \times \text{Low FICO}_i, \text{bank}_i \times \text{log\_assets\_sq}_i \times \text{Low FICO}_i\},$$

where bank_i is an indicator variable for whether the lender is a bank originator, log_assets_i, log_assets_sq_i are continuous variables representing the bank's 2015 log asset size and square of the bank's 2015 asset size, respectively, and Low FICO_i is a dummy variable indicating whether the borrower has FICO<620. Non-banks are assigned a 2015 asset size of 0. Table D.5 shows the results of the weighting in terms of the lender type in Panel A and the mean and standard deviation of asset size among bank lenders in Panel B.

Table D.5. Post-Weighting Summary Statistics on lender type and asset size by FICO Group and Indirect Seller Status

Panel A. Lender type (bank_i)

FICO Group	Seller Type	Pre-Policy Mean	Post-Policy Mean
Low FICO	Indirect Sellers	0.175	0.158
	Other Originators	0.175	0.158
High FICO	Indirect Sellers	0.359	0.325
	Other Originators	0.359	0.325

Panel B. Asset Size (log_assets_i), Among Bank Lenders

FICO Group	Indirect Sellers	Pre-Policy		Post-Policy	
		Mean	SD	Mean	SD
Low FICO	Indirect Sellers	13.806	1.302	13.816	1.292
	Other Originators	13.806	1.302	13.816	1.292
High FICO	Indirect Sellers	14.164	1.465	14.054	1.441
	Other Originators	14.164	1.465	14.054	1.441

E Propensity score weighting of borrower heterogeneity by borrower race and income

In this section we use the covariance-balanced propensity score (CBPS) weighting approach to balance the race (i.e., Black and non-black) and adjusted income of: (1) first-time home buyers and non-first time home buyers, (2) sole-borrowers and borrowers with co-applicants, and (3) borrowers in high self-employment zip codes and borrowers in low self-employment zip codes. We use the methodology of Imai and Ratkovic (2014) to generates weights based on following covariates X_i for each borrower i, separately pre-and-post policy:

$$X_i = \text{race}_i, \text{race}_i \times \text{adjusted\_income}_i, \text{race}_i \times \text{adjusted\_income\_sq}_i, \text{Low FICO}_i$$
$$\text{race}_i \times \text{Low FICO}_i, \text{race}_i \times \text{adjusted\_income}_i \times \text{Low FICO}_i, \text{race}_i \times \text{adjusted\_income\_sq}_i \times \text{Low FICO}_i,$$

where race_i is an indicator variable for whether the borrower is Black, adjusted_income_i, $\text{adjusted\_income\_sq}_i$ are continuous variables representing the application household income divided by the MSA median its square, and Low FICO_i is a dummy variable indicating whether the borrower has FICO<620. Tables D.6 to D.8 show the results of the weighting on race and income.

Table D.6. Post-Weighting Summary Statistics on Race and Income by First Time Home Buyer Status

Panel A. Race (black_i)

FICO Group	First-time Home Buyers	Pre-Policy Mean	Post-Policy Mean
Low FICO	No	0.171	0.119
	Yes	0.171	0.119
High FICO	No	0.183	0.132
	Yes	0.183	0.132

Panel B. Adjusted Income

FICO Group	First-time Home Buyers	Pre-Policy		Post-Policy	
		Mean	SD	Mean	SD
Low FICO	No	1.109	0.490	0.969	0.479
	Yes	1.109	0.490	0.969	0.479
High FICO	No	1.102	0.472	0.984	0.477
	Yes	1.102	0.472	0.984	0.477

Table D.7. Post-Weighting Summary Statistics on Race and Income by Co-Borrower Status

Panel A. Race (black_i)

FICO Group	Has Co-Borrower	Pre-Policy Mean	Post-Policy Mean
Low FICO	Yes	0.179	0.132
	No	0.179	0.132
High FICO	Yes	0.189	0.146
	No	0.189	0.146

Panel B. Adjusted Income

FICO Group	Has Co-Borrower	Pre-Policy		Post-Policy	
		Mean	SD	Mean	SD
Low FICO	Yes	1.019	0.465	0.877	0.429
	No	1.019	0.465	0.877	0.429
High FICO	Yes	1.014	0.450	0.889	0.426
	No	1.014	0.450	0.889	0.426

Table D.8. Post-Weighting Summary Statistics on Race and Income by Self-Employment Zip Code

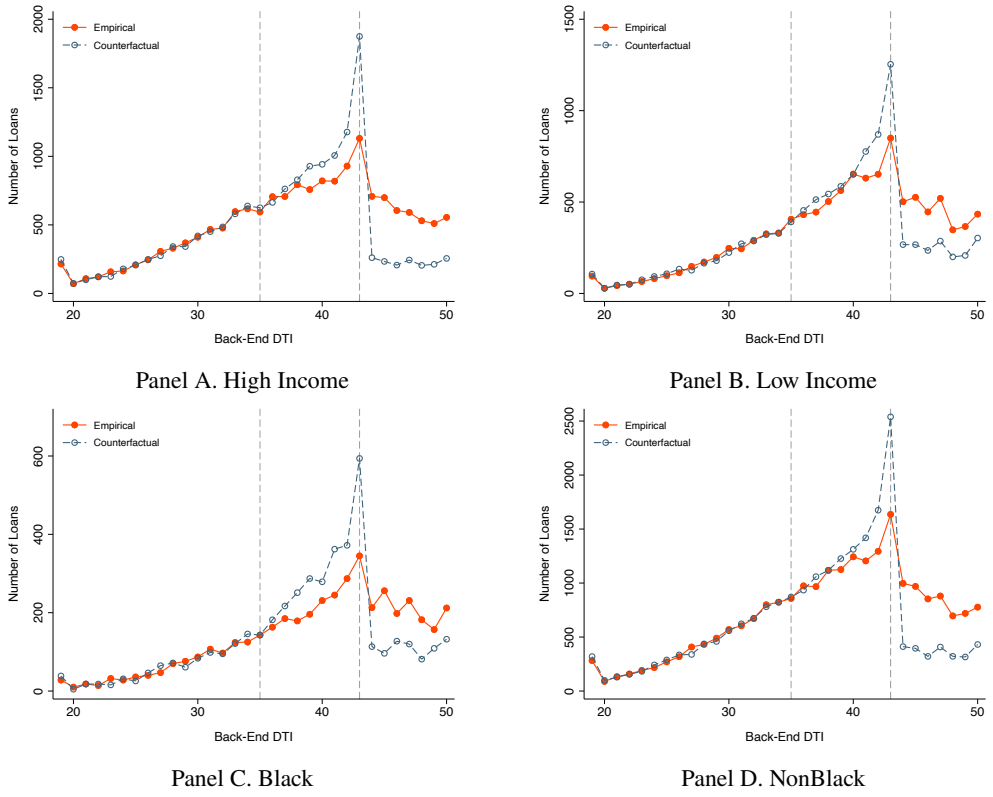
Panel A. Race (black_i)

FICO Group	Self-Employment in Zip Code	Pre-Policy Mean	Post-Policy Mean
Low FICO	Low	0.154	0.105
	High	0.154	0.105
High FICO	Low	0.162	0.115
	High	0.162	0.115

Panel B. Adjusted Income

FICO Group	Self-Employment in Zip Code	Pre-Policy		Post-Policy	
		Mean	SD	Mean	SD
Low FICO	Low	1.216	0.541	1.083	0.531
	High	1.216	0.541	1.083	0.531
High FICO	Low	1.198	0.519	1.094	0.524
	High	1.198	0.519	1.094	0.524

F Bunching subsample graphs



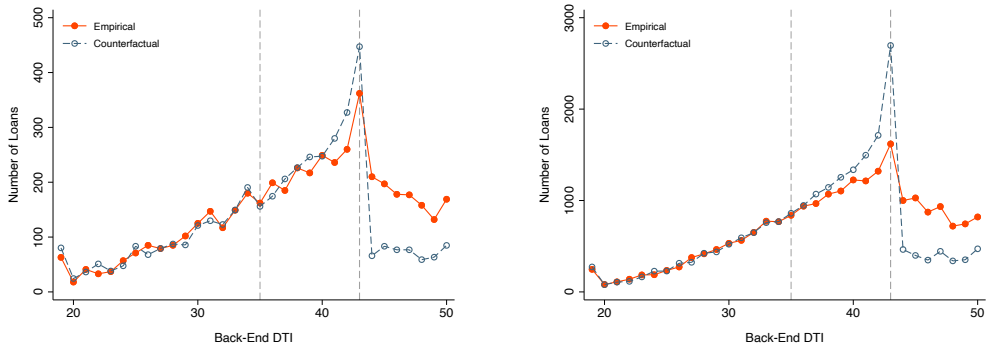
Panel A. High Income

Panel B. Low Income

Panel C. Black

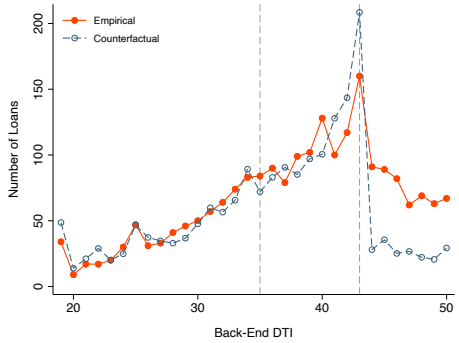
Panel D. NonBlack

Figure D.1. This figure presents heterogeneous changes in credit quantity and DTI distribution around the FHA policy adoption for subsamples of borrower income and race. Panels A and B provide the DTI distributions for borrowers with above- and below-median income, respectively. Panels C and D provide the DTI distributions for Black and non-Black borrowers, respectively. These graphs correspond to the subsample analyses in Table 5

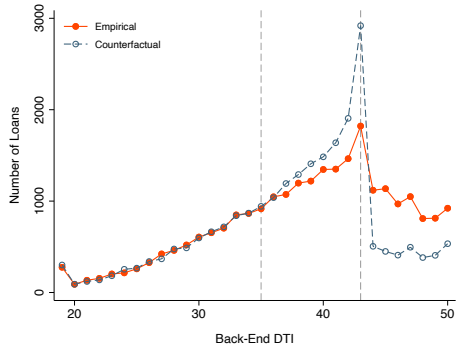


Panel A. Bank Originators

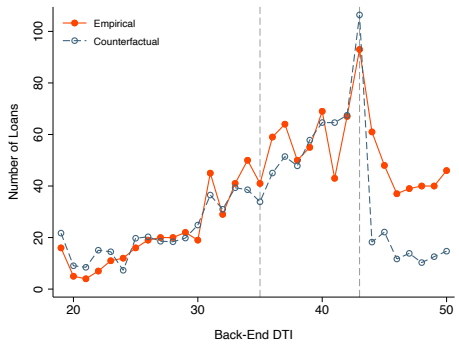
Panel B. Nonbank Originators



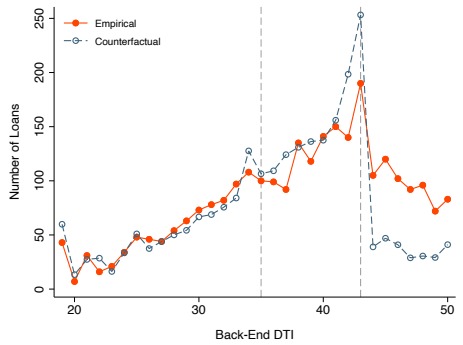
Panel C. Bank Issuers



Panel D. Nonbank Issuers



Panel E. Litigated Banks



Panel F. Non-litigated Banks

Figure D.2. This figure presents the heterogeneous changes in credit quantity and DTI distribution around the FHA policy adoption for subsamples based on lenders' concerns regarding regulatory putback or unobservable human underwriting quality. Panels A and B provide the DTI distributions for bank and nonbank originators, respectively. Panels C and D provide the DTI distributions for bank and nonbank issuers, respectively. Panels E and F provide the DTI distributions for lenders that have and have not faced litigation regarding fraudulent FHA practices, respectively. These graphs correspond to the subsample analyses in Table 6.

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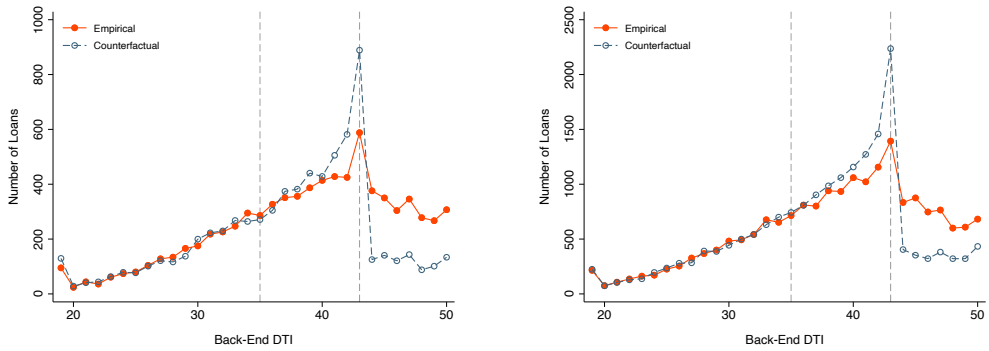
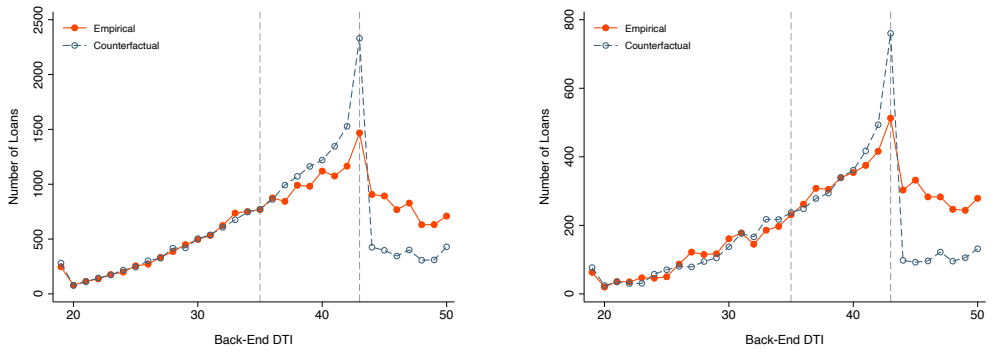


Panel A. Indirect Sellers

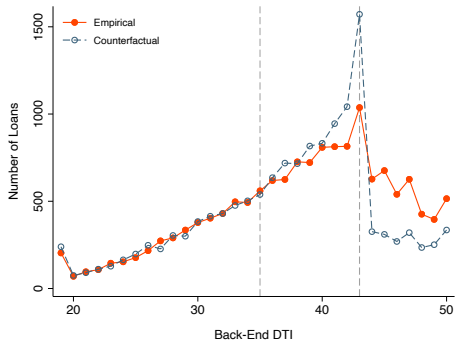
Panel B. Other Originators

Figure D.3. This figure presents heterogeneous changes in credit quantity and DTI distribution around the FHA policy adoption for subsamples based on lenders' concerns regarding unobservable human underwriting quality. Panels A and B compare indirect sellers with other originators, respectively. These graphs correspond to the subsample analyses in Table 7.

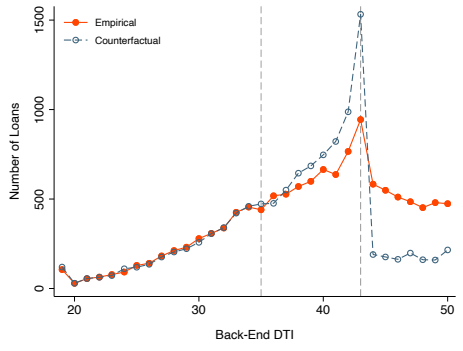


Panel A. First-Time Home Buyers

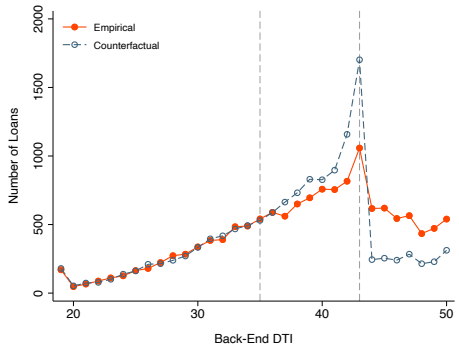
Panel B. Repeat Home Buyers



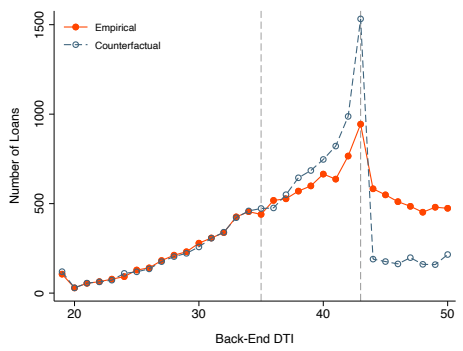
Panel C. Sole Applicants Lenders



Panel D. Having Co-Applicants

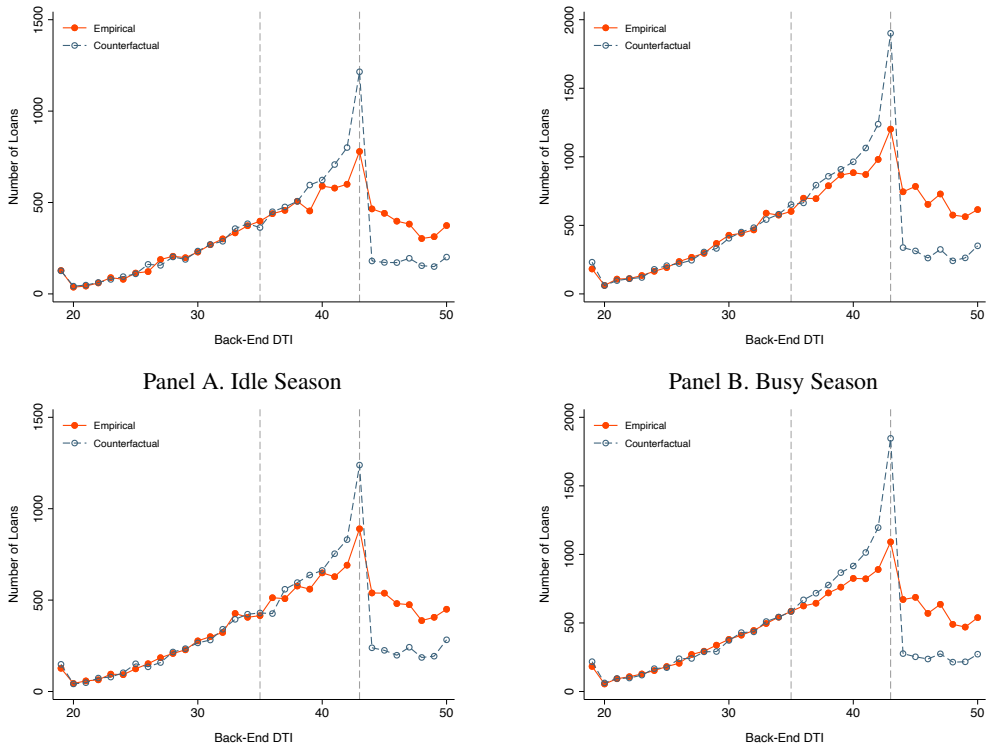


Panel E. High Self-Employment Share



Panel F. Low Self-Employment Share

Figure D.4. This figure depicts the heterogeneous changes in credit quantity and DTI distribution around the FHA policy adoption across borrower characteristics. Panels A and B provide the DTI distributions for first-time and repeat home buyers, respectively. Panels C and D report the results for sole applicants and borrowers with co-applicants, respectively. Panels E and F report the results for borrowers in zip codes with above-median and below-median shares of self-employment income, respectively. These graphs correspond to the subsample analyses in Table 8.



Panel A. Idle Season

Panel B. Busy Season

Panel C. Low Lender-Zip Congestion

Panel D. High Lender-Zip Congestion

Figure D.5. This figure presents heterogeneous changes in credit quantity and DTI distribution around the FHA policy adoption for subsamples related to lender capacity constraints. Panels A and B provide the DTI distributions for idle and busy seasons, respectively. Panels C and D provide the DTI distributions for low and high congestion in a lender-zip code, respectively. These graphs correspond to the subsample analyses in Table E.1.

E Additional Evidence on Economic Mechanisms

Table E.1. Mechanism: Lender Capacity Constraints

This table examines the heterogeneity effects of the FHA underwriting policy across areas and periods with high and low loan application growth. Δ*Loans Originated* refers to the increase in the total number of new purchase loans extended to low FICO borrowers as a fraction of the counterfactual number of new purchase loans extended to low FICO borrowers in the absence of the policy. *g(Volume) (High DTI)* refers to the increase in the total number of new purchase loans extended to borrowers with FICO below 620 and DTI within 43–50 after the policy change as a fraction of the counterfactual number of new purchase loans for those borrowers in the absence of the policy. The methodology is described in Section 4.2. *Difference* represents the difference in coefficient estimates between each subsample partition and the statistical significance of the gap. Panel A reports results where we partition the sample based on months with low and high application volumes. March through August are classified as the "High Season", while September through February are "Low Season." Panel B reports results where we partition the sample based on lender-zips with above-median ("High Congestion") and below-median growth rates of application volume ("Low Congestion"). The sample is our Ginnie Mae-HMDA sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017, excluding August 2016, the month of the policy implementation. DTI is restricted to between 35 to 50. Standard errors are reported in parentheses and are from 1,000 bootstrap replications clustered by origination month. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Panel A: Seasonality

Subsample:	Idle Season	Busy Season	Difference (Idle − Busy)
Outcome: *Volume Change*			
Δ*Loans Originated*	0.053**	0.071***	-0.018
	(0.025)	(0.015)	(0.029)
g(Volume) (High DTI)	1.186***	1.229***	-0.043
	(0.138)	(0.095)	(0.167)

Panel B: Lender-Zip Congestion

Subsampler:	Low Congestion	High Congestion	Difference (Low − High)
Outcome: *Volume Change*			
Δ*Loans Originated*	0.093***	0.054**	0.039
	(0.020)	(0.026)	(0.029)
g(Volume) (High DTI)	1.091***	1.224***	-0.133
	(0.105)	(0.136)	(0.148)

Table E.2. Robustness Tests for Lender Capacity Constraints

This table reports the results from alternative specifications related to measuring lenders' capacity constraints. *g(Volume) (High DTI)* refers to the increase in the total number of new purchase loans extended to borrowers with FICO below 620 and DTI within 43–50 after the policy change as a fraction of the counterfactual number of new purchase loans for those borrowers in the absence of the policy. The methodology is described in Section 4.2. *Difference* represents the difference in coefficient estimates between each subsample partition and the statistical significance of the gap. Panel A reports results where we partition the sample based on lender-tract with above-median and below-median growth rates of application volume; and Panel B reports results where we measure lender-zip congestion using loan application volume excluding FHA applications. The sample is our Ginnie Mae-HMDA sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017. DTI is restricted to between 35 to 50. Standard errors are reported in parentheses and are from 1,000 bootstrap replications clustered by origination month. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Panel A: Lender-Tract Congestion

	Low Lender-Tract Congestion	High Lender-Tract Congestion	Difference
Volume Change			
Δ*Loans Originated*	0.102***	0.062***	0.040
	(0.024)	(0.023)	(0.025)
g(Volume) (High DTI)	1.180***	1.210***	-0.030
	(0.126)	(0.117)	(0.148)

Panel B: Lender-ZIP Congestion, Excluding FHA Applications

	Low Lender-Zip Congestion	High Lender-Zip Congestion	Difference
Volume Change			
Δ*Loans Originated*	0.095***	0.070***	0.025
	(0.029)	(0.025)	(0.034)
g(Volume) (High DTI)	1.196***	1.275***	-0.079
	(0.123)	(0.105)	(0.130)

Table E.3. Mechanism: Lender Entry

This table reports the share of low FICO, high DTI loans post-policy that were made by existing versus new lenders in this market. The sample is our Ginnie Mae-HMDA sample of FHA single-family, non-manufactured housing, home purchase mortgages issued during the period of August 2015 through August 2017. DTI is restricted to between 35 to 50. Standard errors are reported in parentheses and are double clustered by DTI (integer level) and origination month. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

	(1) Existing Lenders	(2) New Lenders
Share of low FICO, high DTI loans	0.805*** (0.004)	0.195*** (0.004)
Number of Lenders	224	394

F Additional Evidence on Neighborhood Quality

Table F.1. Mortgage Access and Neighborhood Choices: Unweighted

This table uses 2SLS specifications to examine the effect of mortgage access on the changes in individuals' local school district ratings. The sample includes individuals in the 1% national representative sample of credit bureau annual records from 2014 to 2019 (excluding 2016), and is merged with the school rating data based on the location of individuals. The unit of observation is an individual-year. Panel A reports first-stage estimates where the dependent variable is an indicator *New Purchase FHA* that equals one if an individual has obtained a new FHA mortgage purchase in a given year. Panel B reports second-stage estimates of the new FHA mortgage purchase on changes in upward mobility, computed as the year-on-year difference. *Treated (2015)* is an indicator that equals one if the borrower's credit score is below 620 in 2015, and zero otherwise. *Post* indicates whether the loan is extended after the regulation change in 2016. Individual characteristics include indicators for gender, marital status, and *Treated (2015)*. Age groups are: 18–35, 35–45, and above 45. A placebo test of this analysis for renters is shown in Appendix Table F.3. Standard errors are reported in parentheses and are clustered by county. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Panel A. First Stage, Obtaining FHA Mortgage

Dep. Var.: *New Purchase FHA*	(1)	(2)	(3)
Treated (2015) × *Post*	0.0019***	0.0019***	0.0019***
	(0.0001)	(0.0001)	(0.0001)
Individual Char	Yes	Yes	Yes
Year FE	Yes		
Credit Score FE	Yes	Yes	Yes
Zip Code FE	Yes		
Age Group FE		Yes	
Zip-Year FE		Yes	Yes
Age Group-Year FE			Yes
Married-Year FE			Yes
Gender-Year FE			Yes
Observations	10,698,445	10,698,445	10,698,445
R^2	0.01	0.01	0.03
F-statistic	380.40	341.31	297.58

Panel B. Moving to Opportunity

Dep. Var:	*d(Up Mob, P25)*		*d(Up Mob, P50)*	
	(1)	(2)	(3)	(4)
New Purchase FHA	0.151***	0.129***	0.151***	0.131***
	(0.024)	(0.024)	(0.023)	(0.023)
Individual Char	Yes	Yes	Yes	Yes
Credit Score FE	Yes	Yes	Yes	Yes
Age Group FE	Yes		Yes	
Zip-Year FE	Yes	Yes	Yes	Yes
Age Group-Year FE		Yes		Yes
Married-Year FE		Yes		Yes
Gender-Year FE		Yes		Yes
Observations	10,670,325	10,670,325	10,670,325	10,670,325

Table F.2. Mortgage Access and Neighborhood Choices: Other Mobility Measures

This table reports the second-stage estimates of the 2SLS approach, which examines the effect of mortgage access on "moving to opportunity." The sample includes individuals in the 1% national representative sample of credit bureau annual records from 2014 to 2019 (excluding 2016), and is merged with the upward mobility and neighborhood characteristics measures obtained from Chetty et al. (2025) based on the location of individuals. We exclude individuals that have obtained a mortgage with DTI above 50 in the past. The unit of observation is an individual-year. The dependent variables represent year-on-year changes in upward mobility of an individual's census tract of residence. *School Rating* measures the public school district rating of the zip code. *Household Income* measures average household income. *Poverty Share* measures the share of individuals in the tract below the federal poverty line. *Frac College* measures the number of people aged 25 or older who have a bachelor's degree, master's degree, professional school degree, or doctorate degree, divided by the total number of people aged 25 or older in a tract. *Single Parent Share* measures the number of households with female heads (and no husband present) or male heads (and no wife present) with own children under 18 years old present divided by the total number of households with own children present. *Treated (2015)* is an indicator that equals one if the borrower's Vantage Score is below 620 in 2015, and zero otherwise. *Post* indicates whether the loan is extended after the regulation change in 2016. Individual characteristics include indicators for gender, marital status, and *Treated (2015)*. Age groups are: 18–35, 35–45, and above 45. Standard errors, clustered by county, are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Dep. Var:	*d(School Rating)*		*d(Household Income)*		*d(Poverty Share)*		*d(Frac College)*		*d(Single Parent Share)*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
New Purchase FHA	1.2693**	1.1906**	36,970.908***	13,633.639	-0.188***	-0.109**	0.599***	0.517***	-0.282***	-0.162*
	(0.5440)	(0.5047)	(13,931)	(12,875)	(0.060)	(0.054)	(0.081)	(0.074)	(0.101)	(0.091)
Individual Char	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Credit Score FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age Group FE	Yes		Yes		Yes		Yes		Yes	
Year-Zip FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Gender FE		Yes		Yes		Yes		Yes		Yes
Year-Age Group FE		Yes		Yes		Yes		Yes		Yes
Year-Marriage Status FE		Yes		Yes		Yes		Yes		Yes
Observations	10,661,657	10,661,657	10,662,328	10,662,328	10,662,706	10,662,706	10,640,338	10,640,338		

Table F.3. Mortgage Access and the Quality of Neighborhoods: Placebo Test Using Renters

The unit of observation is an individual-year. The sample is limited to individuals in the Experian dataset with a consistent dwelling status of "A" (indicating residence in apartments, condominiums, or other multi-family units) throughout the sample period. This selection criterion helps identify likely renters, following the approach of Butler et al. (2019). The outcome variables, specified at the top of each column, are detailed in the notes to Tables 10 and F.2. *Treated (2015)* is an indicator that equals one if the borrower's credit score is below 620 in 2015, and zero otherwise. *Post* indicates whether the loan is extended after the regulation change in 2016. Individual characteristics include indicators for gender, marital status, and *Treated (2015)*. The fixed effects specification is the same as the specification of the even-numbered columns in Table 10. Standard errors are reported in parentheses and are clustered by county. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Var:	*d(School Rating)*	*d(Up Mob, P25)*	*d(Up Mob, P50)*	*d(Household Income)*	*d(Poverty Share)*	*d(Frac College)*	*d(Single Parent Share)*
Treated (2015) × *Post*	-0.004	-0.000	0.000	61.519	-0.000	-0.000	-0.001
	(0.003)	(0.000)	(0.000)	(103.606)	(0.000)	(0.000)	(0.001)
Individual Char	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Credit Score FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Zip FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Gender FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Marriage Status FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	480,174	479,304	479,304	479,827	479,925	479,946	476,911
R^2	0.126	0.095	0.091	0.097	0.100	0.093	0.094